U.S. DEPARTMENT OF COMMERCE
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PB-268 337

Possum Kingdom Reservoir Palo Pinto, Stephens, and Young Counties, Texas

National Eutrophication Survey, Corvallis, Oreg

Prepared for

Corvallis Environmental Research Lab, Oreg

Mar 77

PB 268 337

U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY
WORKING PAPER SERIES

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON
and
ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA

1. REPORT NO. 2.

4. TITLE AND SUBTITLE
Report on Possum Kingdom Reservoir, Palo Pinto, Stephens, and Young Counties, Texas

5. REPORT DATE
Prepared March 1977

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Anonymous (National Eutrophication Survey Staff)

8. PERFORMING ORGANIZATION REPORT NO.
Working Paper # 665

9. PERFORMING ORGANIZATION NAME AND ADDRESS
National Eutrophication Survey
U.S. Environmental Protection Agency
200 S. W. 35th St.
Corvallis, Oregon 97330

10. PROJECT/TASK/WORK UNIT NO.

11. CONTRACT/GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS
Office of Research and Development
U.S. Environmental Protection Agency
401 M Street, S. W.
Washington, DC 20460

13. TYPE OF REPORT AND PERIOD COVERED
Final - 1974

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
Prepared in cooperation with the U.S. Environmental Protection Agency, National Environmental Research Center, Las Vegas, Nevada 89114

16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
eutrophication lakes nutrients phosphorus nitrogen loading		08H 08C
18. AVAILABILITY STATEMENT Release unlimited	19. SECURITY CLASS (This Report)	21. NO. OF PAGES 15
	20. SECURITY CLASS (This Page)	22. PRICE PC A02/MF A01

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EPA Form 2220-1 (9-73)

Report
on
Possum Kingdom Reservoir
Palo Pinto, Stephens, and Young Counties
Texas
EPA Region VI
Working Paper No. 655

With the cooperation of the
Texas Water Quality Board
and the
Texas National Guard
March, 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Texas Water Quality Board for professional involvement, to the Texas National Guard for conducting the tributary sampling phase of the Survey, and to those Texas wastewater treatment plant operators who voluntarily provided effluent samples.

Hugh C. Yantis, Jr., Executive Director of the Texas Water Quality Board, and John B. Latchford, Jr., Director, and the staff of the Field Operations Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General Thomas Bishop, the Adjutant General of Texas, and Project Officer Colonel William L. Seals, who directed the volunteer efforts of the Texas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

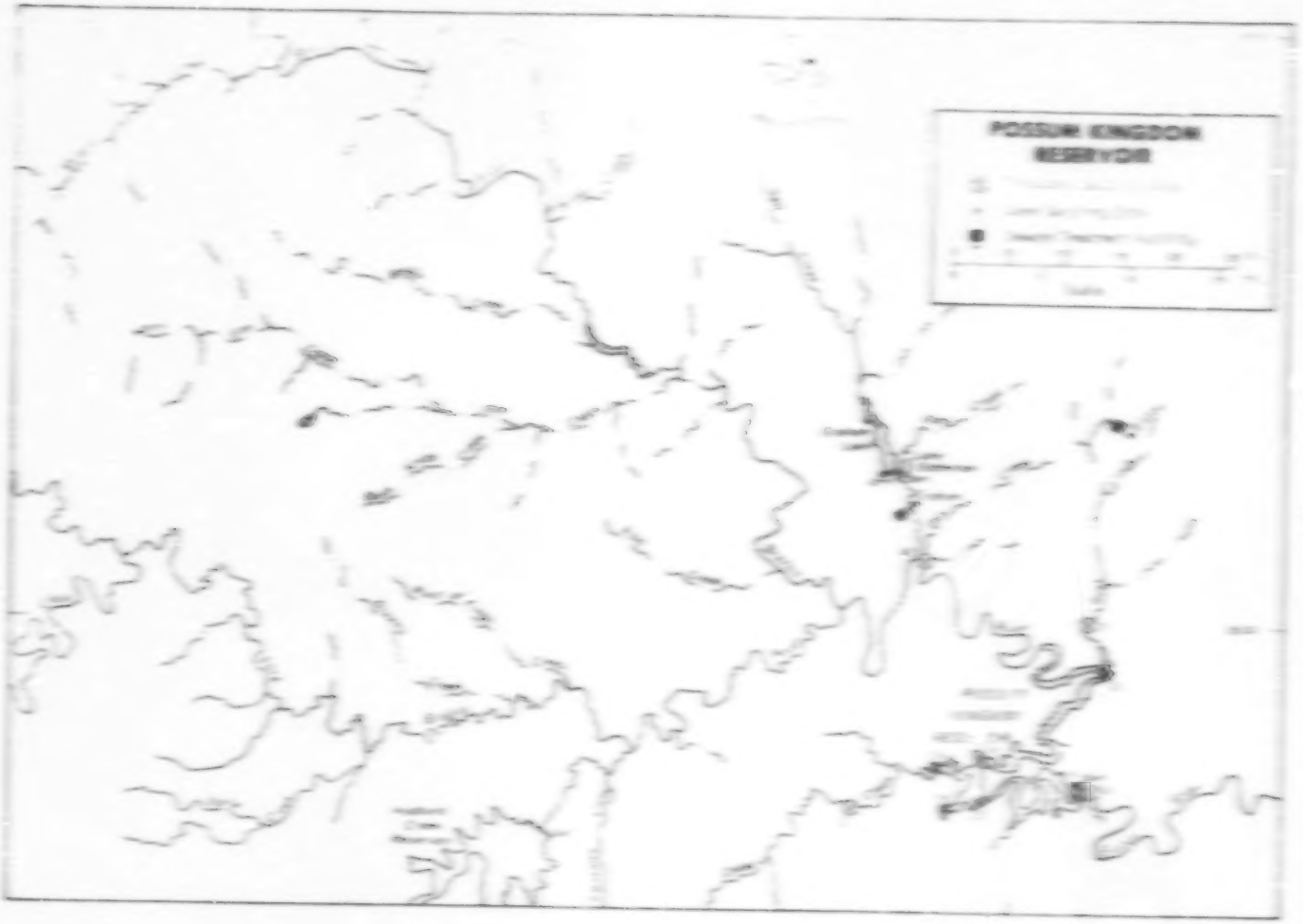
NATIONAL EUTROPHICATION SURVEY

STUDY RESERVOIRS

State of Texas

NAME	COUNTY
Amistad	Val Verde
Bastrop	Bastrop
Belton	Bell, Coryell
Braunig	Bexar
Brownwood	Brown
Buchanan	Burnet, Llano
Caddo	Harrison, Marion, TX; Caddo Parish, LA
Calaveras	Bexar
Canyon	Comal
Colorado City	Mitchell
Corpus Christi	Jim Wells, Live Oak, San Patricio
Diversion	Archer, Baylor
Eagle Mountain	Tarrant, Wise
Fort Phantom Hill	Jones
Houston	Harris
Kemp	Baylor
Lake O'The Pines	Camp, Marion, Morris, Upshur
Lavon	Collin
Lewisville (Garza-Little Elm)	Denton
Livingston	Polk, San Jacinto, Trinity, Walker

Lyndon B. Johnson	Burnet, Llano
Medina	Bandera, Medina
Meredith	Hutchinson, Moore, Potter
O. C. Fisher (San Angelo)	Tom Green
Palestine	Anderson, Cherokee, Henderson, Smith
Possum Kingdom	Palo Pinto, Stephens, Young
Sam Rayburn	Angelina, Jasper Nacogdoches, Sabine, San Augustine
Somerville	Burleson, Lee, Washington
E. V. Spence	Coke
Stamford	Haskell
Stillhouse Hollow	Bell
Tawakoni	Hunt, Rains, Van Zandt
Texoma	Cooke, Grayson TX; Bryon, Johnston, Love, Marshall, OK
Travis	Burnet, Travis
Trinidad	Henderson
Twin Buttes	Tom Green
White River	Crosby
Whitney	Bosque, Hill
Wright Patman (Texarkana)	Bowie, Cass


POSSUM KINGDOM
RESERVOIR

POSSUM KINGDOM RESERVOIR
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I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Possum Kingdom Reservoir is meso-eutrophic; i.e., moderately-well supplied with nutrients and productive. Whether nutrient enrichment is beneficial or deleterious depends on the actual or potential effect on the uses of the reservoir. In this regard, no nuisance conditions are known to personnel of the Texas Water Quality Board and there is little or no impairment of the designated beneficial uses of this water body.

Possum Kingdom Reservoir ranked ninth when the 39 Texas reservoirs sampled in 1974 were compared using a combination of six parameters*. Nine of the reservoirs had less and one had the same median total phosphorus, 11 had less and six had the same median dissolved orthophosphorus, two had less and three had the same median inorganic nitrogen, 16 had less mean chlorophyll *a*, and six had greater mean Secchi disc transparency. Marked depression or depletion of hypolimnetic dissolved oxygen occurred at sampling stations 1, 2, 3 and 4 in May and August, and depression or depletion with depth occurred at the same stations in October,

* See Appendix A.

B. Rate-limiting Nutrient:

Due to significant losses of total phosphorus in the algal assay samples from the times of collection to the beginning of the assays, the results are not representative of conditions in the reservoir at the times the samples were taken (03/08/74 and 10/30/74).

The reservoir data indicate nitrogen limitation at all stations in March, phosphorus limitation at all stations except station 5 in May, nitrogen limitation at all stations except station 4 in August, and nitrogen limitation at all stations in October.

C. Nutrient Controllability:

1. Point sources--The point-source phosphorus contribution amounted to 4.2% of the total load reaching Possum Kingdom Reservoir during the sampling year. The City of Graham contributed 3.9% of the total load, the community of Bryson added 0.2%, and septic tanks serving lakeside dwellings were estimated to have contributed 0.1% of the total.

The present phosphorus loading of 2.70 $g/m^2/yr$ is four times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 15). Regardless of the applicability of Vollenweider's eutrophic level to Texas reservoirs, it is not likely that elimination of point-source phosphorus would significantly improve the trophic condition of the reservoir because of the large non-point load.

8. Non-point sources--Over 95% of the total phosphorus input to Possum Kingdom Reservoir during the sampling year came from non-point sources. The Brazos River contributed 91.1%; Cedar Creek, 1.3%; and Rock Creek, 0.5% of the total load. The ungaged tributaries were estimated to have contributed 2.2%.

The Brazos River, Cedar Creek, and Rock Creek had phosphorus export rates of 3, 8, and 4 kg P/km²/yr, respectively (see page 14). These rates are slightly higher than two tributaries of nearby Lake Brownwood* (1 and 3 kg P/km²/yr) and higher than a tributary of Lake Colorado City** (1 kg P/km²/yr).

* Working Paper No. 630.
** Working Paper No. 640.

II. RESERVOIR AND DRAINAGE BASIN CHARACTERISTICS†

A. Morphometry††:

1. Surface area: 80.13 kilometers².
2. Mean depth: 11.2 meters.
3. Maximum depth: 44.2 meters.
4. Volume: 897,456 x 10^3 m^3.
5. Mean hydraulic retention time: 1 year (based on outflow).

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Brazos River	56,736.5	25.02
Cedar Creek	347.1	0.83
Rock Creek	274.5	0.67
Minor tributaries & immediate drainage -	966.3	2.01
Totals	58,324.4	28.59

2. Outlet -

Brazos River	58,404.6**	28.24**

C. Precipitation***:

1. Year of sampling: 83.6 centimeters.
2. Mean annual: 65.6 centimeters.

† Table of metric conversions--Appendix B.
†† Latchford, 1974.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of reservoir; lesser outflow due to evaporation (Yost, 1976).
*** See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Possum Kingdom Reservoir was sampled four times during 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at five stations on the reservoir in March and May and from six stations in August and October (see map, page vi). During each visit, a single depth-integrated (4.6 m to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first and last visits, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll *a* analysis. The maximum depths sampled were 28.0 meters at station 1, 21.3 meters at station 2, 15.2 meters at station 3, 10.0 meters at station 4, 7.9 meters at station 5, and 9.8 meters at station 6.

The sampling results are presented in full in Appendix D and are summarized in the following table.

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6. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
05/08/74	1. Chroomonas sp.	1,391
	2. Oocystis sp.	1,089
	3. Scenedesmus sp.	614
	4. Ankistrodesmus sp.	91
	5. Pennate diatoms	60
	Other genera	121
	total	3,366
08/16/74	1. Chroomonas sp.	778
	2. Tetraedron sp.	733
	3. Certeria sp.	412
	4. Oocystis sp.	366
	5. Ankistrodesmus sp.	183
	Other genera	448
	total	2,930
09/09/74	1. Lyngbya sp.	3,649
	2. Anabaenopsis sp.	1,622
	3. Raphidiopsis sp.	538
	4. Merismopedia sp.	595
	5. Anabaena sp.	378
	Other genera	1,540
	total	8,622
10/30/74	1. Oscillatoria sp.	6,224
	2. Dactylococcopsis sp.	2,948
	3. Chroomonas sp.	837
	4. Oocystis sp.	665
	5. Raphidiopsis sp.	437
	Other genera	1,093
	total	12,194

B. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
03/06/74	1	2.1
	2	2.4
	3	2.5
	4	1.9
	5	3.1
	6	-
05/16/74	1	1.5
	2	2.0
	3	2.5
	4	2.1
	5	10.6
	6	-
08/09/74	1	6.3
	2	6.1
	3	15.9
	4	14.3
	5	27.0
	6	14.5
10/30/74	1	10.9
	2	8.7
	3	15.9
	4	19.1
	5	27.7
	6	10.8

C. Limiting Nutrient Study:

There were significant losses of total phosphorus in the algal assay samples from the time of collection to the beginning of the assays. Therefore, the results are not representative of conditions in the reservoir at the time the samples were collected in March and October, 1974.

The reservoir data indicate a temporal and spatial combination of limiting nutrients. Following is a tabulation of the mean inorganic nitrogen/orthophosphorus ratios for each of the sampling stations and times with the indicated limiting nutrient in parentheses. Note that station 5, closest to point sources, was nitrogen limited at all sampling times, while the stations further away were phosphorus limited at times.

Station	03/08/74	05/16/74	08/09/74	10/30/74
01	6/1 (N)	18/1 (P)	4/1 (N)	4/1 (N)
02	10/1 (N)	32/1 (P)	8/1 (N)	8/1 (N)
03	10/1 (N)	26/1 (P)	13/1 (N?)	5/1 (N)
04	12/1 (N)	33/1 (P)	19/1 (P)	9/1 (N)
05	7/1 (N)	9/1 (N)	10/1 (N)	7/1 (N)
06	-	-	11/1 (N)	8/1 (N)

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Texas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for the high runoff months of April and May when two samples were collected. Sampling was begun in September, 1974, and was completed in August, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Texas District Office of the U.S. Geological Survey for the tributary sites nearest the reservoir.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads, in kg/km^2/year, at stations A-2, C-1, and D-1 and multiplying the means by the ZZ area in km^2.

The operator of the Bryson wastewater treatment plant provided monthly effluent samples and corresponding flow data. The City of Graham did not participate; nutrient loads from this source were estimated at 1.134 kg P and 3.401 kg N/capita/year, and flows were estimated at 0.3785 m^3/capita/day.

* See Working Paper No. 175.

A. Waste Sources:

1. Known municipal -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Bryson*	445	sand filter	90.5	Trib. of Rock Creek
Graham**	7,500	tr. filter	2,006.1	Salt Creek

2. Known industrial - None

* Walden, 1974; Anonymous, 1971.
** Anonymous, 1971.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Brazos River	197,390	91.1
Cedar Creek	2,810	1.3
Rock Creek	1,050	0.5
b. Minor tributaries & immediate drainage (non-point load) -	4,830	2.2
c. Known municipal STP's -		
Bryson	425	0.2
Graham	8,905	3.9
d. Septic tanks* -	255	0.1
e. Known industrial - None	-	-
f. Direct precipitation** -	1,400	0.7
Total	216,665	100.0

2. Outputs -

Lake outlet - Brazos River 29,835

3. Net annual P accumulation - 186,830 kg.

* Estimate based on 875 lakeshore dwellings, 2 campgrounds, and two picnic areas; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Brazos River	1,356,570	83.0
Cedar Creek	45,720	2.8
Rock Creek	26,315	1.6
b. Minor tributaries & immediate drainage (non-point load) -	81,170	5.0
c. Known municipal STP's -		
Bryson	805	0.1
Graham	25,510	1.6
d. Septic tanks* -	9,535	0.6
e. Known industrial - None	-	-
f. Direct precipitation** -	86,510	5.3
Total	1,632,135	100.0

2. Outputs -

Lake outlet - Brazos River 1,006,145

3. Net annual N accumulation - 625,990 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Brazos River	3	14
Cedar Creek	8	132
Rock Creek	4	96

* Estimate based on 875 lakeshore dwellings, 2 campgrounds, and two picnic areas; see Working Paper No. 175.
** See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	2.70	2.33	20.4	7.8

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Possum Kingdom Reservoir:

"Dangerous" (eutrophic loading)	0.66
"Permissible" (oligotrophic loading)	0.33

V. LITERATURE REVIEWED

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VI. APPENDICES

APPENDIX A

LAKE RANKINGS

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[illegible] CODE	[illegible] NAME	[illegible] TOTAL *	[illegible] [illegible] %	[illegible] [illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible] [illegible] *
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28	[illegible]	[illegible]	[illegible]

LAKE NUMBER AND INDEX NO.

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30	[illegible]	TEXAS LAKE	217
31	[illegible]	[illegible] LAKE	200
32	[illegible]	[illegible]	208
33	[illegible]	TEXARKANA LAKE	176
34	[illegible]	[illegible]	173
35	[illegible]	TEXOMA	164
36	[illegible]	[illegible] LAKE	159
37	[illegible]	CORPUS CHRISTI LAKE	155
38	[illegible]	[illegible]	136
39	[illegible]	LIVINGSTON LAKE	91

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107 x 10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

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APPENDIX D

PHYSICAL and CHEMICAL DATA

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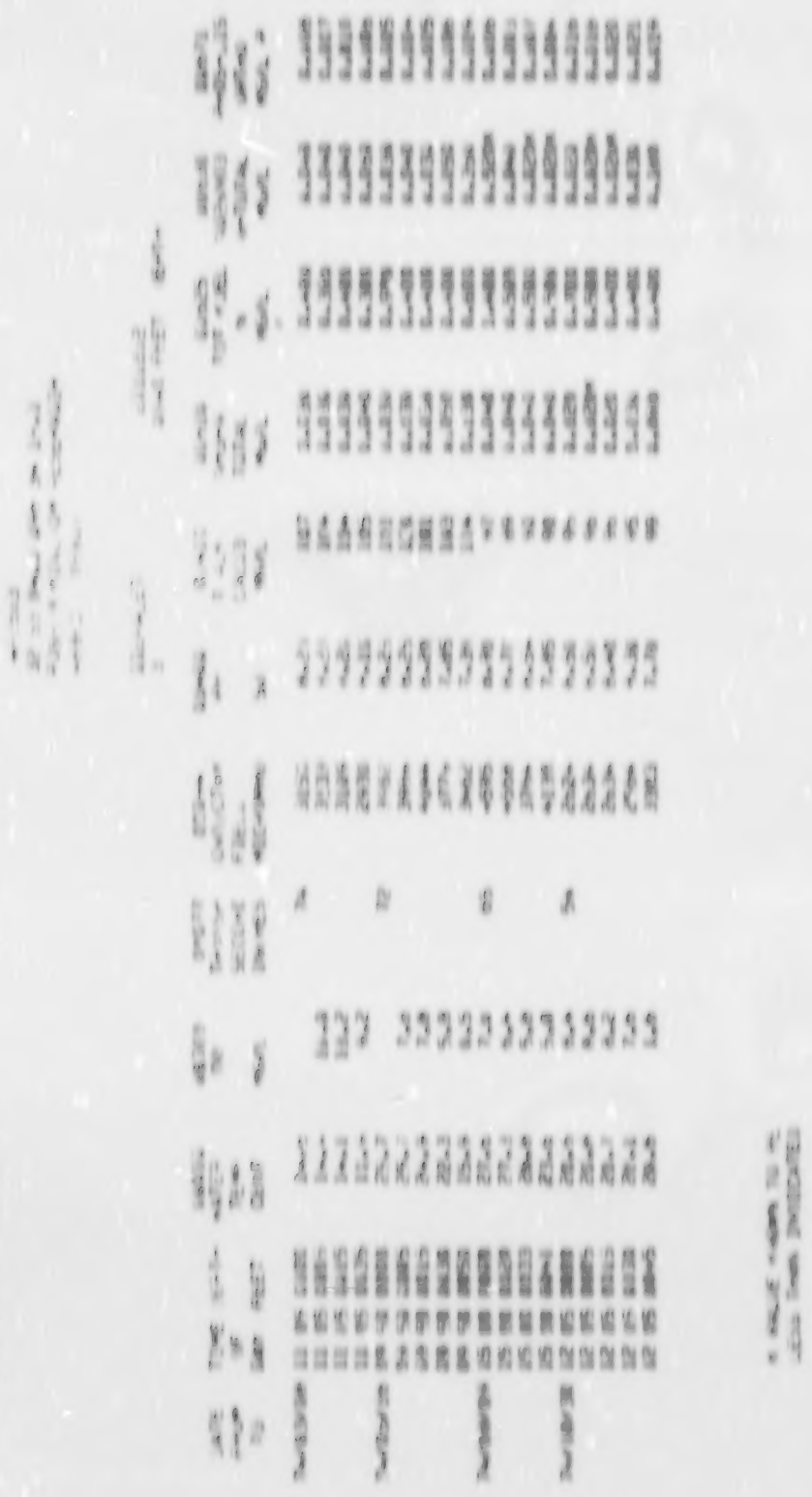

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APPENDIX E

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

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* VALUE KNOWN TO BE
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